PROJECT facts

U.S. Department of Energy
Office of Fossil Energy
National Energy Technology Laboratory

Petroleum Exploration and Production

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Development of Shallow Viscous Oil Reserves on the North Slope

PARTNERS

University of Houston
Houston, TX

MAIN SITES

North Slope, AK

Background

Prudhoe Bay on Alaska's North Slope is the largest oil field in North America. Linked to Prudhoe Bay field and producing from the same formations is Kuparuk River field, ranked the second largest producing field in the country. Heavy oil presents the biggest potential for undeveloped reserves on the North Slope; the target original-oil-in-place resource is estimated at 10-20 billion barrels.

Although these reservoirs are the largest undeveloped heavy oil accumulations in North America, recovery has proved a daunting challenge for North Slope operators. The producing formations lie at depths of 3,000-5,000 ft in a region of deep permafrost, which causes the heavy oil to become extremely viscous. An economic method of recovery for this enormous heavy oil resource has been the goal of North Slope operators for years.

The North Slope fields have been exploited since the 1970s, and both Prudhoe Bay and Kuparuk River fields are now in decline. Over 20% of the Nation's oil supply is carried by the Trans-Alaska Pipeline System (TAPS), but production declines have reduced the volume carried by 25% from its peak throughput. Further declines in production will make TAPS uneconomic to operate unless new resources can be developed to increase the daily volume. Conversely, once TAPS becomes uneconomic to operate, the remaining North Slope oil resource would be lost as a potential future oil supply to America. So commercial development of North Slope heavy oil has taken on a critical urgency.

Project Description/Accomplishments

Heavy oil samples from three North Slope reservoirs—Ugnu, West Sak, and Schrader Bluff—were studied to determine the optimal means to increase recovery. The high oil viscosity coupled with low formation strength of the reservoirs has led to the use of water-alternating-gas injection (WAG) at West Sak and Schrader Bluff. (The even higher viscosities encountered in the Ugnu formation forestalls its development pending a technology advance.)

The goal is to develop tools to determine the optimum solvent, injection schedule, and well architecture for a WAG process that would be economic for North Slope shallow heavy oil reservoirs.

The research consisted of corefloods, a 5-spot field study, compositional simulation, wettability, relative permeability analyses, and streamlined simulations of WAG processes and the effects of potential chemical changes. The simulation results confirmed that injection of CO_2 in combination with natural gas liquids (NGL) was superior to produced Prudhoe Bay natural gas plus NGL. The studies found that three hydrocarbon phases formed at pressures of 1,300-1,800 psi were applicable for

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PROJECT DATA

DE-FC26-01BC15186
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Total Project Value
$744,250

DOE/Non-DOE Share
$594,250/$150,000

CUSTOMER SERVICE

1-800-553-7681

WEBSITE

www.netl.doe.gov

injection. As the mean thickness of the adsorbed organic layer on the minerals increased, the oil-water contact angle increased. The adsorbed organic films left behind after extraction by aromatic solvents (toluene and decalin) used in core studies are thinner than those left behind by non-aromatic solvents such as cyclohexane. The adhesion of minerals with the asphaltene fraction of the heavy oil implied that asphaltenes are responsible for the mixed wettability problem in the reservoirs.

The information was used to design a new relative-permeability model for a four-phase, mixed-wet system. The streamlined module developed can be incorporated into existing finite-difference-based compositional simulator models for water floods, gas floods, and WAG floods.

The laboratory studies combined with field analysis indicated that horizontal wells increase recovery significantly versus vertical wells but that sweep efficiency may decrease. Overall well performance was found to depend on well length, position of the borehole, formation heterogeneity, and viscosity ratio.

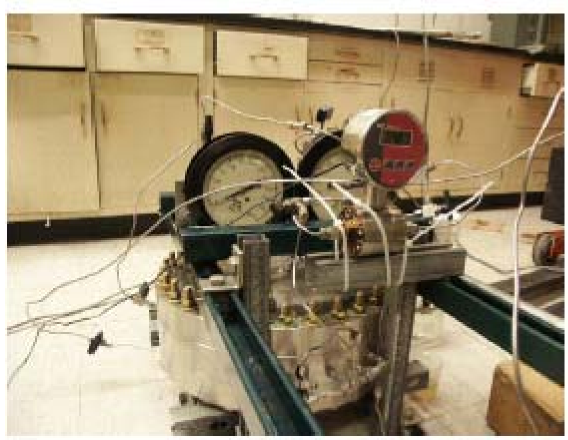
Production also increased due to electromagnetic heating, which was a function of the power intensity, flow rate, and frequency of stimulation. Electromagnetic heating as a means of well stimulation was shown to be capable of doubling oil production.

Tests of the high-pressure 5-spot model were conducted to evaluate the sweep efficiency of miscible WAG floods. WAG displacement processes reduced bypassing compared with gas floods and improved oil recovery in core experiments. As the WAG ratio decreased and the slug size grew, oil recovery increased. Greater slug size accelerated the oil recovery rate and decreased the WAG ratio in simulated field studies.

Benefits/Impacts

The results of the research established the EOR methods that will yield the highest recovery from the North Slope heavy oil reservoirs. CO_2-NGL injection works better than injection of Prudhoe Bay natural gas-NGL. Simulation modeling demonstrated the best strategy for timing and volume of WAG floods. Although sweep efficiency may decrease somewhat, horizontal wells were found to produce more heavy oil than did vertical wells. The factors that influence horizontal well performance were identified and can be used to plan horizontal wellbores and predict recovery. In addition, the use of electromagnetic heating of the reservoir can double the production of heavy oil.

The combination of new technologies and a better understanding of what methods work best in Alaskan heavy oil reservoirs could increase North Slope heavy oil production significantly and thus ensure continued TAPS flow.



The 5-spot high-pressure cell constructed to evaluate sweep efficiency of miscible WAG floods.